USAFETAC/PR--91/009

PERSIAN GULF CONTRAIL ALTITUDE LIMITS

by

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13. Abstract: Describes development of a computer program (DNCONTRL) that determines the mean and extreme upper and lower limits for conditions that favor condensation trail formation over a given upper-air reporting station. Output of the DNCONTRL program is provided in tabular form for 19 stations in the Persian Gulf region, not only as upper and lower altitudes for the formation of contrails, but as monthly percent occurrence frequency (POF) for favorable contrail formation at specified altitudes. These results were compared with an earlier, similar, study for the entire northern hemisphere and found to be consistent.

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PREFACE

When USAFETAC/DNO was tasked to determine upper and lower altitude limits for contrail formation over a specified area of the Persian Gulf, they found that there was no operational capability for doing so. This report describes the development of such a capability, one that was then used to determine monthly climatological altitude limits (extreme minimum, mean minimum, mean maximum, extreme maximum) for contrail formation over a given upper-air station.

To determine climatological altitude limits, project analyst Capt Gregory J. Reding developed a computer program named "DNCONTRL." With Maj Walter F. Miller and Capt Brian M. Bjornson, he used DNCONTRL to examine 19 upper-air stations in the specified area of interest to determine the desired mean and extreme altitude limits for each station.

Information on percent occurrence frequency (POF) of conditions favoring contrail formation over individual stations was also determined and is included in the report, along with data previously developed and published in 3rd Weather Manual 105-9, *Monthly Climatological Condesnation Trail Probabilities over the Northern Hemisphere.*

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1. INTRODUCTION.

1.1 Overview. USAFETAC/DNO was tasked to find the upper and lower limits of contrail formation over a specified part of the Persian Gulf region. Since USAFETAC had no operational capability to do this, it developed a computer program (known as "DNCONTRL") to find monthly climatological extreme minimums, mean minimums, extreme maximums, and mean maximum altitudes (in feet above mean sea level--MSL) favorable for contrail formation, over a given upper-air station. DNCONTRL uses upper-air data from the entire period of record (POR) for each station studied. The program also produces tables that give monthly percent occurrence frequency (POF) of contrail formation conditions for specified levels in the atmosphere. Fortunately, the meteorological data required to compute the requested statistics was readily available; USAFETAC/DNO was able to forward the statistics to the operational customer quickly.

1.2 Product Description. This report provides the upper and lower altitude limits for contrail formation, as well as POFs of conditions that are favorable for contrail formation. It does ***not*** provide upper and lower altitude limits of *observed* contrails.

1.3 Computing Upper and Lower Limits of Contrail Formation. To provide common levels at which to compute POFs of favorable contrail conditions for all soundings in a given station's period of record (POR), all upper-air data was first interpolated to 500-foot intervals in the vertical. The DNCONTRL program then determined if conditions were right for contrail formation at each level in an upper-air sounding by computing the critical temperature for contrail formation with an equation taken from USAFETAC/PR-90/003 (see 3.2). This critical temperature, a function of pressure and relative humidity, was computed for each level in a sounding. If the ambient temperature at a level was less than or equal to the critical temperature, contrail formation was considered possible. Minimum and maximum altitudes for contrail formation from each sounding in a station's POR were used to compute the monthly mean minimum and maximum contrail formation altitudes and to select the monthly extreme minimum and maximum altitudes.

1.4 Application of DNCONTRL to the Persian Gulf. To examine contrail formation conditions in the area of interest, the program was run with data from 19 upper-air sounding stations within an area bounded by 10° to 40° N, and 30° to 60° E. Monthly extreme minimum, mean minimum, mean maximum, and extreme maximum contrail formation altitudes were calculated for each station, along with monthly POFs of favorable contrail conditions at 500-foot intervals.

2. DATA.

2.1 Upper-Air Stations Used. Figure 1 lists the 19 upper-air stations used in the study.

Station	Block Station Number	Latitude	Longitude	Elevation (meters)	POR
Ankara, TU	171300	39°57' N	32°53' E	894	73-88
Izmir, TU	172200	38°26' N	27°10' E	25	73-88
Isparta, TU	172400	37°45' N	30°33' E	997	73-88
Diyarbakir, TU	172800	37°53' N	40°11' E	677	73-88
Aleppo/Neirab, SY	400070	36°11' N	37°13' E	393	73-87
Damascus, SY	400800	33°25' N	36°31' E	611	73-88
Bet Dagan, IS	401790	32°00' N	34°49' E	30	73-88
Tabuk, SD	403750	28°22' N	36°38' E	770	76-88
Madinah, SD	404300	24°33' N	39°42' E	631	80-88
Riyadh, SD	404370	24°56' N	46°13' E	612	73-88
Dhahran, SD	404160	26°16' N	50°09' E	17	75-88
Kuwait IAP, KW	405820	29°13' N	47°59' E	55	73-90
Baghdad, IQ	406500	33°14' N	44°14' E	34	73-90
Mashhad, IR	407450	36°16' N	59°38' E	980	73-80
Tehran, IR	407540	35°41' N	51°21' E	1,191	73-80
Kerman, IR	408410	30°15' N	56°58' E	1,754	73-80
Khamis Mushait, SD	411140	18°18' N	42°48' E	2,054	76-88
Seeb, OM	412560	23°55' N	58°17' E	15	82-88
Salalah, OM	413160	17°02' N	54°05' E	20	80-88

Figure 1. Upper-air stations used in the study.

2.2 Input Data Description. PORs of historical weather data available for analysis varied widely among the 19 stations, and ranged from 8 to 18 years. For each station, data from 10,000 feet MSL to either 100,000 feet MSL or the top of the sounding, whichever was lower, was extracted from magnetic tape for use in DNCONTRL. We chose 10,000 feet MSL as the lower limit after a preliminary review of 3WWM 105-9, *Monthly Climatological Condensation Trail Probabilities Over the Northern Hemisphere*, which indicated no probability of contrails over the Gulf region at or below 500 millibars (about 18,000 feet MSL) for any month of the year. Soundings were interpolated to 500-foot intervals in the vertical as USAFETAC/ECA read them from tape using ECAUARDR, the standard program for retrieving upper-air data. A 500-foot interval was chosen to ensure that all significant variations in the temperature, pressure, or humidity profiles of the soundings were accounted for when computing critical temperature (see 3.2). Information for each level in these files includes:

- Block Station Number (6-digits)
- Year (2-digits)
- Month (2-digits; e.g., 01)
- Day (2-digits; e.g., 02)
- Hour (2-digits; eg., 03)
- Height (geopotential feet MSL)
- Temperature (degrees Celsius)
- Pressure (millibars)
- Relative Humidity (percent)

Sounding data from the 19 upper-air stations was stored on disk in EBCDIC-format "flat files" before processing by DNCONTRL. EBCDIC is a standard format for representing binary data used by IBM computers; it is used on USAFETAC's IBM 3090 mainframe. Flat files require less disk space than other data formats, and st. allow rapid retrieval by DNCONTRL.

2.3 Tropopause Data. USAFETAC/ECA also created files containing tropopause height for each station's soundings. Tropopause height is necessary for calculating critical temperature, as will be described in Section 3. These files consisted of:

- Block Station Number (6-digits)
- Year (2-digits)
- Month (2-digits; e.g., 01)
- Day (2-digits; e.g., 02)
- Hour (2-digits; eg., 03)
- Tropopause Height (geopotential feet MSL)

Including tropopause height in the same files as the thermodynamic data would have taken too much time when the data was read from tape. For simplicity, it was decided to create separate tropopause data files, and then combine them with the rest of the data with DNCONTRL computer routines as they were needed. To be read by DNCONTRL, which was written in Statistical Analysis System (SAS)[1] language, these tropopause height files were stored as SAS permanent datasets (PDSs). Sounding data, originally created as flat files, was converted to SAS PDSs when DNCONTRL needed it by still another program (EXTRCDTG), which is referenced in DNCONTRL's job control language (JCL).

1. SAS is a registered trademark of the SAS Institute Inc., Cary, NC.

3. SOFTWARE.

3.1 Basic Design. Minimum and maximum altitudes for possible contrail formation in the Persian Gulf area were required for all months. DNCONTRL was designed to find monthly mean and extreme minimum and maximum levels at which contrails could form over a given upper-air station. The program was run using data from each of the 19 stations in the area to describe the spatial variations throughout the region precisely.

3.2 Determining Contrail Formation Altitudes: Critical Temperature. The critical temperature equation shown here was developed from data in Table 1 of AWS/TR-81/001 by statistical regression techniques. It is used to determine whether or not contrails can form at a given altitude, and was applied to each level in a given sounding. It was also used to determine levels of possible contrail formation in USAFETAC/PR-90/003, *SAC Contrail Forecasting Algorithm Validation Study*, which compared several contrail forecasting algorithms.

$$T_c = -93.9 + 4.92 \cdot ln(p) + 0.45 \cdot [ln(p)^2] + 0.30 \cdot RH - 0.0074 \cdot (RH^2) + 0.000053(RH^3)$$

where

T_c = critical temperature required for contrail formation at a given pressure and relative humidity (°C)

p = pressure at a given level in the atmosphere (mb)

RH = relative humidity at a given level in the atmosphere (%)

The critical temperature computed at each level in the sounding is compared to the ambient temperature at that level. If the ambient temperature is less than or equal to the critical temperature, contrail formation is possible. A "flag," with a value of "yes" or "no, is assigned to each level in the sounding, depending on whether or not contrail formation was possible.

3.3 Developing POF Tables. DNCONTRL uses SAS's **TABULATE** procedure to produce monthly tables that give POFs of conditions favorable for contrails for each level in the vertical. Those tables are provided in Section 5, "Results."

3.4 Computing Mean and Extreme Minimums and Maximums. SAS's **MEANS** procedure allowed extraction of the lowest and highest altitudes at which contrail formation was possible for each sounding. By operating on this extracted data a second time with the **MEANS** procedure, the monthly extreme minimum, mean minimum, mean maximum, and extreme maximum altitudes for contrail formation were computed.

3.5 Replacing Missing Data.

3.5.1 ***Relative Humidity.*** Relative humidity (RH) is necessary for determining whether or not contrails will form at a given altitude. Since it is frequently missing in soundings above 400 mb, DNCONTRL uses the following artificial profile (taken from the Air Force Global Weather Central (AFGWC) contrail forecasting program) to fill in missing RH data:

- Troposphere: 40 percent
- Within 300 meters of the tropopause: 70 percent
- Stratosphere: 10 percent

Substituting these values requires knowledge of where the tropopause is for each sounding. As already mentioned USAFETAC/ECA created files of tropopause heights for each sounding. These were then merged with the thermodynamic sounding data using SAS procedures included in DNCONTRL.

3.5.2 ***Tropopause Height.*** Monthly mean tropopause heights are computed by DNCONTRL using information on individual tropopause heights for a given station. For soundings in which a value of tropopause height is missing, monthly mean values are substituted.

4. TESTING AND VALIDATION.

4.1 Restrictions on Use of Critical Temperature. The T_c equation given in 3.2 is only valid to 72,000 feet MSL. It was derived from data in Table 1 of AWS/TR-81/001, which contains data for pressure levels from the surface to 40 mb--about 72,000 ft MSL. Since the relationship in the equation is almost linear, it was used beyond that altitude; however, inferences of contrail formation above 72,000 feet MSL have not been checked against actual observations, and conditions favorable for contrail formation above this limit are questionable.

To examine their validity, mean and extreme minimums and maximums were determined for two different datasets. The first set contained all soundings in a station's POR. To eliminate obviously questionable contrail detection altitudes, the second contained only soundings in which no favorable contrail conditions were detected at the top of the sounding. Analysts then compared the extreme maximum contrail altitudes from these two sets for each station. If there was a discrepancy between extreme maximum altitudes for a given location and month, analysts looked at the POF tables for that station and month to see (a) if the questionable extreme maximum altitude was an "outlier"; that is, an instance of possible contrail formation isolated from any other such regions and above 72,000 feet, or (b) if the maximum was part of a large region of possible contrail formation. Figure 2 shows a situation in which there is a difference in extreme maximum altitude between the two datasets. Output from DNCONTRL for Tabuk in February yields two different values of extreme maximum altitude: 73,500 and 90,000 feet MSL.

	Number of Observations	Mean	Standard Deviation	Lowest Maximum (ft)	Highest Maximum (ft)
Statistics for levels at which contrails may form	576	62,963.54	6,366.25	34,500	90,000
Statistics for levels at which the top level has no contrail	436	65,018.35	3,394.16	35,000	73,500

Figure 2. Results from DNCONTRL showing different values of extreme maximum contrail formation height for Tabuk, Saudi Arabia, in February.

The table that gives POFs of favorable contrail conditions by altitude for Tabuk in February was then consulted to decide which was correct. That portion of the Tabuk POF table that gives data from 70,000 to 90,000 ft MSL is given in Figure 3.

Altitude (ft)	Number of Occurrences	Percent Frequency
70,000	17	4.3
70,500	11	8.0
71,000	8	2.1
71,500	4	1.0
72,000	3	0.8
72,500	3	0.8
73,000	3	0.8
73,500	2	0.5
74,000	2	0.5
74,500	2	0.6
75,000	2	0.6
76,000	2	0.6
76,500	2	0.6
77,000	2	0.6
77,500	1	0.3
78,000	1	0.3
78,500	1	0.4
79,000	1	0.5
79,500	1	0.4
80,000	1	0.4
80,500	1	0.4
81,000	1	0.5
81,500	1	0.5
82,000	1	0.5
82,500	2	1.0
83,000	2	1.0
83,500	2	1.0
84,000	2	1.0
84,500	2	1.0
85,000	2	1.0
85,500	0	0.0
86,000	0	0.0
86,500	0	0.0
87,000	0	0.0
87,500	0	0.0
88,000	1	0.9
88,500	1	0.9
89,000	1	1.0
89,500	1	1.0
90,000	1	1.0

Figure 3. POF of contrail formation conditions for Tabuk, Saudi Arabia, in February.

Figure 3 shows that the extreme maximum of 90,000 feet was included in an area of possible contrail formation that started at 88,000 feet MSL. Coupled with a general trend of decreasing percent frequencies from well below 72,000 up to 85,000 feet MSL, analysts concluded that an extreme maximum of 90,000 feet was believable. In all cases in which such a discrepancy existed, the higher of the two extreme maximum altitudes was selected as the actual extreme maximum.

4.2 Manual Verification of DNCONTRL Computations. DNCONTRL computations of critical temperature values were checked manually; the software correctly computes critical temperature. To evaluate DNCONTRL's ability to calculate the monthly mean and extreme minima and maxima, the program was then run on a small dataset consisting of three individual soundings. The extreme minimum and maximum contrails calculated by DNCONTRL were compared to those determined manually for the same three soundings. The results were identical. It was concluded that DNCONTRL correctly determines the mean and extreme altitudes of contrail formation, as determined by the critical temperature equation in 3.2, for any given dataset.

4.3 Comparison with 3rd Weather Wing Manual 105-9. Although no published contrail climatology was identical to the USAFETAC study, 3WWM 105-9, *Monthly Climatological Condensation Trail Probabilities Over the Northern Hemisphere*, was similar in that it also provides monthly tables giving probability of contrail formation at mandatory pressure levels over the Persian Gulf region. Although a true comparision of the two sets of statistics was not possible, at least some agreement was evident. Differences and similarities are discussed below.

4.3.1 *Differences:*

The 3WWM 105-9 data was computed for and is displayed at mandatory pressure levels from 850 to 100 mb. USAFETAC data was calculated for 500-foot levels from 10,000 ft MSL to the top of each sounding.

Contrail formation probabilities in 3WWM 105-9 were computed for the center point of 5-degree latitude by 5-degree longitude quadrangles for the northern hemisphere. POFs of favorable contrail formation conditions in the USAFETAC study were calculated for specific upper-air stations.

3WWM 105-9 used fixed values of critical temperature and monthly mean temperatures at each mandatory pressure level to determine if contrails might form at those levels. The USAFETAC study determined critical temperature at each 500-foot level as a function of pressure and relative humidity (see 3.2).

The monthly probability of contrail formation given by 3WWM 105-9 at a mandatory pressure level was determined as a function of: (1) the difference between the mean monthly height of that level and the mean monthly height of the tropopause, and (2) the standard deviation of temperature at that level for that month. See 3WWM 105-9 and AWSTR 105-104,

An Estimate of the Contrail Problem, for a more complete explanation of the method. Although USAFETAC's POF of conditions favoring contrail formation is fundamentally different than a "probability," they are both thought of as the chance of an event occurring.

3WWM 105-9 used monthly mean temperature data at mandatory pressure levels from 3WWM 105-4, *World Mean Monthly Upper Air Temperatures*. The data used to compute these means was not the same for all levels (as shown below), while the PORs used in USAFETAC/PR--91/009 vary for each upper-air station, as shown below.

For 850 and 700 mb.....5-year POR, 1946-1950

For 500, 400 and 300 mb.....6-year POR, 1950-1955

For 200 and 100 mb.....5-year POR, 1949-1953

For 150 mb.....2-year POR, 1941 and 1952

4.3.2 *Similarities:*

Both studies show increased possibility of contrail formation with height. To illustrate, see Figures 4a-f and 5. Figures 4a-f (from 3WWM 105-9) give the probability of contrail formation for the eastern hemisphere in January for 850, 700, 500, 300, 200, 150, and 100 mb. The Persian Gulf region is outlined by a rectangle. Figure 5 gives data extracted from the DNCONTRL's POF of favorable January contrail formation conditions for Riyadh, Saudi Arabia (24° 56' N, 46° 13' E, which lies in the approximate center of the boxes in Figures 4a-f), for January.

Results of the USAFETAC study indicate that conditions are not favorable for contrail formation below 17,000 feet (about 535 mb) anywhere in the Persian Gulf region at any time of year. 3WWM 105-9 draws a similar conclusion in that it shows no possibility of contrail formation below 500 mb (about 18,000 feet) for any month in this region. This is corroborated by Figure 2, which shows no contrail occurrences below that level.

Figure 4d indicates no chance for contrails at 300 mb (30,000 feet MSL) in the central portion of the region; data from Figure 5 at this altitude supports this finding. Figure 4e (3WWM 105-9) indicates a 65- to 69% chance of contrails for this location at 200 mb (39,000 ft MSL), while Figure 5 (DNCONTRL) shows a 60% POF of contrails at that altitude. Figure 4f indicates a 97-99% chance for contrails at 150 mb (45,000 ft); Figure 5 gives a 95% POF. Both studies claim a 100-percent incidence of favorable contrail conditions at 100 mb (53,000 feet MSL).

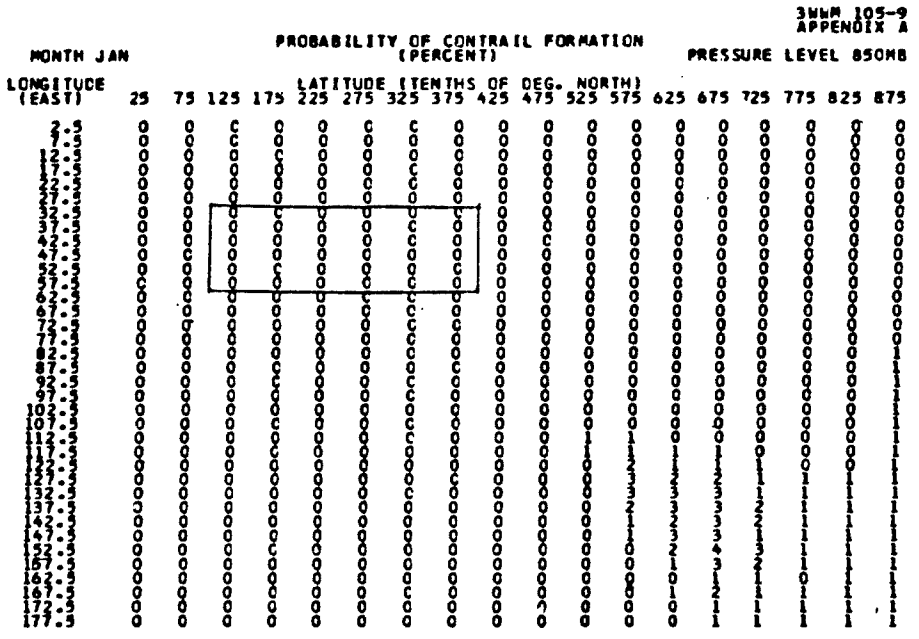

Figure 4a. January probability of contrail formation conditions at 850 mb, from 3WWM 105-9. The rectangle outlines the Persian Gulf region.

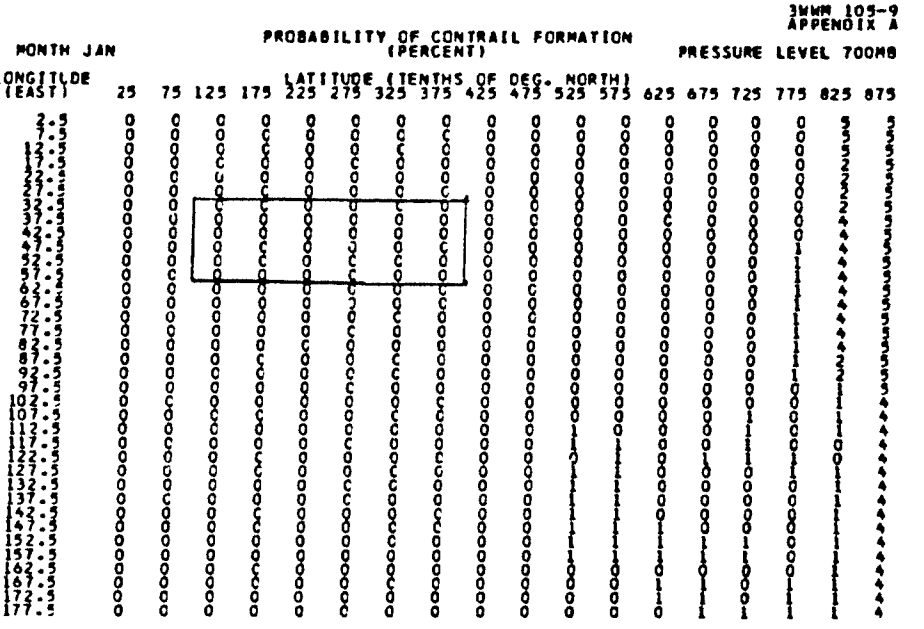

Figure 4b. January probability of contrail formation conditions at 700 mb, from 3WWM 105-9. The rectangle outlines the Persian Gulf region.

3WWM 105-9
APPENDIX A

PROBABILITY OF CONTRAIL FORMATION (PERCENT)

MONTH JAN PRESSURE LEVEL 500MB

LONGITUDE (EAST)	LATITUDE (TENTHS OF DEG. NORTH) 25	75	125	175	225	275	325	375	425	475	525	575	625	675	725	775	825	875
2.5	0	0	0	0	0	0	0	0	0	0	0	1	2	5	9	16	27	34
7.5	0	0	0	0	0	0	0	0	0	0	0	1	2	5	12	16	27	34
12.5	0	0	0	0	0	0	0	0	0	0	1	1	2	7	12	16	27	34
17.5	0	0	0	0	0	0	0	0	0	0	1	2	3	7	12	16	27	34
22.5	0	0	0	0	0	0	0	0	0	0	2	2	5	7	8	16	27	34
27.5	0	0	0	0	0	0	0	0	0	0	2	3	5	9	12	16	27	34
32.5	0	0	0	0	0	0	0	0	0	0	2	3	7	9	12	16	27	34
37.5	0	0	0	0	0	0	0	0	0	0	2	5	7	9	12	16	27	34
42.5	0	0	0	0	0	0	0	0	0	0	3	5	9	12	12	16	27	34
47.5	0	0	0	0	0	0	0	0	0	0	3	5	9	12	12	21	27	34
52.5	0	0	0	0	0	0	0	0	0	2	3	7	9	12	16	21	27	34
57.5	0	0	0	0	0	0	0	0	0	2	3	7	9	16	16	21	27	34
62.5	0	0	0	0	0	0	0	0	0	2	3	7	12	12	16	21	27	34
67.5	0	0	0	0	0	0	0	0	0	2	3	7	12	12	21	27	34	42
72.5	0	0	0	0	0	0	0	0	0	2	3	7	8	16	21	27	34	42
77.5	0	0	0	0	0	0	0	0	0	1	5	9	8	16	21	27	34	42
82.5	0	0	0	0	0	0	0	0	0	1	5	9	12	21	27	34	34	42
87.5	0	0	0	0	0	0	0	0	0	2	5	9	12	21	27	34	34	42
92.5	0	0	0	0	0	0	0	0	0	2	7	12	16	27	31	34	34	42
97.5	0	0	0	0	0	0	0	0	0	3	7	16	21	34	31	34	42	42
102.5	0	0	0	0	0	0	0	0	0	3	9	20	27	34	40	42	42	42
107.5	0	0	0	0	0	0	0	0	0	3	12	25	34	42	40	42	42	42
112.5	0	0	0	0	0	0	0	0	0	5	16	27	34	42	42	42	42	42
117.5	0	0	0	0	0	0	0	0	2	7	20	34	42	42	42	42	42	42
122.5	0	0	0	0	0	0	0	0	5	9	25	34	50	50	42	42	42	42
127.5	0	0	0	0	0	0	0	0	5	12	25	42	50	50	42	42	42	42
132.5	0	0	0	0	0	0	0	0	5	16	31	42	50	50	42	42	42	42
137.5	0	0	0	0	0	0	0	0	5	16	25	37	42	42	42	42	42	42
142.5	0	0	0	0	0	0	0	0	5	16	25	37	42	42	42	42	42	42
147.5	0	0	0	0	0	0	0	0	5	12	20	31	37	42	42	42	42	42
152.5	0	0	0	0	0	0	0	0	1	12	16	25	37	37	34	42	42	42
157.5	0	0	0	0	0	0	0	0	1	4	12	20	31	37	37	42	42	42
162.5	0	0	0	0	0	0	0	0	0	2	8	16	25	31	37	37	42	42
167.5	0	0	0	0	0	0	0	0	0	1	7	12	16	25	37	37	42	42
172.5	0	0	0	0	0	0	0	0	0	0	3	7	12	24	31	37	42	42
177.5	0	0	0	0	0	0	0	0	0	0	2	5	9	20	25	37	42	42

Figure 4c. January probability of contrail formation conditions at 500 mb, from 3WWM 105-9. The rectangle outlines the Persian Gulf region.

3WWM 105-9
APPENDIX A

PROBABILITY OF CONTRAIL FORMATION (PERCENT)

MONTH JAN PRESSURE LEVEL 300MB

LONGITUDE (EAST)	LATITUDE (TENTHS OF DEG. NORTH) 25	75	125	175	225	275	325	375	425	475	525	575	625	675	725	775	825	875
2.5	0	0	0	0	0	0	12	43	59	65	73	81	87	95	97	98	100	100
7.5	0	0	0	0	0	0	12	43	65	73	81	87	92	95	97	98	100	100
12.5	0	0	0	0	0	0	12	43	73	81	87	92	95	97	97	99	100	100
17.5	0	0	0	0	0	0	12	57	88	87	92	92	95	97	98	99	100	100
22.5	0	0	0	0	0	0	12	57	88	92	95	95	97	97	98	99	100	100
27.5	0	0	0	0	0	0	12	57	88	92	95	97	97	98	99	99	100	100
32.5	0	0	0	0	0	0	12	57	88	92	97	97	98	100	100	100	100	100
37.5	0	0	0	0	0	0	12	57	88	92	97	97	98	100	100	100	100	100
42.5	0	0	0	0	0	0	12	69	93	92	97	98	98	100	100	100	100	100
47.5	0	0	0	0	0	2	19	65	81	97	99	98	99	99	100	100	100	100
52.5	0	0	0	0	0	2	19	55	81	97	99	100	99	99	100	100	100	100
57.5	0	0	0	0	0	2	19	55	81	97	99	100	99	100	100	100	100	100
62.5	0	0	0	0	0	4	19	55	81	97	99	100	99	100	100	100	100	100
67.5	0	0	0	0	0	4	18	55	81	97	99	100	99	100	100	100	100	100
72.5	0	0	0	0	0	4	18	55	81	97	99	100	100	100	100	100	100	100
77.5	0	0	0	0	1	4	18	55	81	97	99	100	100	100	100	100	100	100
82.5	0	0	0	0	1	4	18	45	81	95	99	100	100	100	100	100	100	100
87.5	0	0	0	0	0	4	18	45	81	95	99	100	100	100	100	100	100	100
92.5	0	0	0	0	0	2	14	46	81	95	100	100	100	100	100	100	100	100
97.5	0	0	0	0	0	1	14	46	81	95	100	100	100	100	100	100	100	100
102.5	0	0	0	0	0	1	5	38	81	95	98	100	100	100	100	100	100	100
107.5	0	0	0	0	0	0	5	38	81	95	98	99	100	100	100	100	100	100
112.5	0	0	0	0	0	0	5	38	73	95	98	99	100	100	100	100	100	100
117.5	0	0	0	0	0	0	3	31	73	95	98	99	100	100	100	100	100	100
122.5	0	0	0	0	0	0	2	31	69	95	98	99	100	100	100	100	100	100
127.5	0	0	0	0	0	0	4	31	69	92	98	99	100	100	100	100	100	100
132.5	0	0	0	0	0	0	4	31	62	92	98	99	100	100	100	100	100	100
137.5	0	0	0	0	0	0	2	31	62	92	98	99	100	100	100	100	100	100
142.5	0	0	0	0	0	0	2	31	69	92	97	99	99	100	100	100	100	100
147.5	0	0	0	0	0	0	10	38	69	92	97	98	99	100	100	100	100	100
152.5	0	0	0	0	0	0	10	31	62	92	97	98	99	99	100	100	100	100
157.5	0	0	0	0	0	0	7	31	62	82	95	97	98	99	99	100	100	100
162.5	0	0	0	0	0	0	4	24	54	76	92	95	97	98	99	100	100	100
167.5	0	0	0	0	0	0	2	18	46	73	87	95	97	98	99	100	100	100
172.5	0	0	0	0	0	0	2	18	38	65	81	92	95	97	98	100	100	100
177.5	0	0	0	0	0	0	2	18	38	55	73	87	95	97	98	100	100	100

Figure 4d. January probability of contrail formation conditions at 300 mb, from 3WWM 105-9. The rectangle outlines the Persian Gulf region.

3WWM 105-9
APPENDIX A

MONTH JAN — PROBABILITY OF CONTRAIL FORMATION (PERCENT) — PRESSURE LEVEL 200MB

LONGITUDE (EAST)	LATITUDE (TENTHS OF DEG. NORTH) 25	75	125	175	225	275	325	375	425	475	525	575	625	675	725	775	825	875
2.5	60	60	57	57	69	73	76	77	86	86	86	82	82	86	89	89	93	96
7.5	60	60	57	57	69	73	76	72	82	86	86	82	86	86	89	89	96	96
12.5	60	60	60	57	69	73	76	76	82	86	86	82	86	86	89	89	96	96
17.5	60	60	60	69	69	73	76	76	82	82	86	86	90	86	89	93	96	96
22.5	60	60	60	77	69	73	76	76	82	82	86	86	90	90	89	93	93	96
27.5	60	60	77	77	69	73	81	76	82	82	86	86	90	90	86	93	93	96
32.5	60	60	77	77	69	73	81	81	82	82	86	86	90	90	90	93	93	96
37.5	60	60	60	77	69	73	81	81	82	82	86	86	90	90	90	93	93	93
42.5	60	60	60	60	69	65	81	81	82	82	86	86	90	90	90	93	93	93
47.5	60	60	60	57	69	65	81	81	82	82	86	86	90	90	90	90	93	93
52.5	60	60	60	57	57	65	81	81	82	86	86	86	90	90	90	90	93	93
57.5	60	57	57	57	55	65	81	76	82	86	86	86	90	90	90	90	93	93
62.5	69	69	57	55	55	62	76	76	82	92	92	92	86	90	90	90	93	93
67.5	69	69	65	55	54	62	76	76	82	92	92	92	86	90	90	90	90	93
72.5	69	80	73	55	54	62	76	76	82	92	92	92	86	90	90	90	90	93
77.5	69	80	73	65	54	62	76	76	87	87	92	92	86	90	90	90	90	93
82.5	77	80	80	65	55	62	76	76	87	87	92	92	86	90	90	90	90	93
87.5	77	80	80	57	55	69	76	76	87	87	92	92	86	86	90	90	90	93
92.5	77	77	69	57	57	65	81	81	87	87	92	92	92	86	90	90	90	93
97.5	77	77	60	57	57	65	73	81	87	87	87	92	86	86	86	90	90	93
102.5	60	60	60	43	43	57	65	73	81	87	87	92	86	86	86	90	90	93
107.5	60	60	60	40	43	43	57	65	73	81	87	87	86	86	86	90	90	93
112.5	60	60	60	40	31	31	45	45	65	73	87	87	86	86	86	90	90	93
117.5	60	60	60	40	31	20	35	35	45	65	81	87	82	86	86	90	90	93
122.5	77	60	60	40	31	20	27	27	35	55	73	81	82	86	86	90	90	93
127.5	77	60	60	60	43	27	19	24	31	45	65	81	82	82	86	86	90	93
132.5	77	77	60	60	43	27	24	18	24	35	55	73	76	82	86	86	90	93
137.5	77	77	60	60	43	27	24	18	24	31	45	65	76	82	86	86	90	93
142.5	77	77	60	60	43	31	24	14	18	31	45	65	76	82	86	86	90	93
147.5	77	77	60	57	45	31	24	18	18	24	35	55	69	82	86	86	90	93
152.5	77	77	60	57	45	31	28	18	18	18	38	55	69	76	86	86	90	93
157.5	77	77	60	57	45	38	28	18	18	18	31	54	69	76	77	86	90	93
162.5	60	77	60	57	55	38	31	23	18	23	31	46	62	76	77	86	93	93
167.5	60	77	69	57	55	46	38	28	23	23	31	46	62	76	77	86	93	93
172.5	60	60	69	69	55	54	54	40	34	28	31	46	62	72	77	86	93	93
177.5	60	60	69	69	65	62	62	47	40	34	31	46	60	72	77	86	93	93

Figure 4e. January probability of contrail formation conditions at 200 mb, from 3WWM 105-9. The rectangle outlines the Persian Gulf region.

3WWM 105-9
APPENDIX A

MONTH JAN — PROBABILITY OF CONTRAIL FORMATION (PERCENT) — PRESSURE LEVEL 150MB

LONGITUDE (EAST)	LATITUDE (TENTHS OF DEG. NORTH) 25	75	125	175	225	275	325	375	425	475	525	575	625	675	725	775	825	875
2.5	100	100	100	98	97	92	76	54	46	47	47	54	54	69	76	82	86	82
7.5	100	100	100	100	98	87	73	54	46	46	46	54	62	69	82	86	86	82
12.5	100	100	100	100	98	87	73	46	46	38	46	54	62	76	82	86	86	82
17.5	100	100	100	100	98	87	73	45	38	38	45	55	73	81	82	86	86	82
22.5	100	100	100	100	98	93	73	45	35	35	45	55	65	81	82	86	86	82
27.5	100	100	100	100	98	93	73	45	38	38	35	55	65	81	82	86	86	82
32.5	100	100	100	100	99	93	73	45	35	27	38	45	62	69	76	82	86	82
37.5	100	100	100	100	99	97	73	45	27	27	38	46	62	69	76	82	86	82
42.5	100	100	100	100	99	97	81	45	27	27	38	46	54	69	76	82	82	82
47.5	100	100	100	100	99	97	81	45	27	27	31	46	54	62	76	82	82	82
52.5	100	100	100	100	100	92	81	55	27	31	31	46	54	62	69	76	82	82
57.5	100	100	100	100	98	95	82	54	27	24	31	38	54	62	69	76	82	82
62.5	100	100	100	100	97	90	82	54	38	24	31	38	46	62	69	76	82	82
67.5	100	100	100	99	98	89	82	62	38	24	24	38	46	62	69	76	82	82
72.5	100	100	100	99	96	89	82	62	38	24	24	31	46	54	60	76	82	82
77.5	100	100	100	99	96	89	86	62	38	24	24	31	46	53	60	76	82	82
82.5	100	100	100	99	96	89	82	54	38	24	24	31	46	53	60	76	82	82
87.5	100	100	100	100	98	93	82	54	38	24	24	31	46	53	60	76	82	82
92.5	100	100	100	100	99	97	82	54	31	24	24	31	46	53	60	76	82	82
97.5	100	100	100	100	100	95	81	45	31	24	24	31	46	53	60	76	82	82
102.5	100	100	100	100	100	92	73	35	24	24	24	31	46	53	60	76	82	82
107.5	100	100	100	100	100	92	65	27	24	24	24	31	46	53	60	76	82	82
112.5	100	100	100	100	99	87	55	24	14	18	24	31	46	53	60	76	82	82
117.5	100	100	100	100	98	81	46	14	7	10	18	31	46	53	60	76	82	82
122.5	100	100	100	100	98	81	46	10	4	7	18	31	46	60	66	76	82	82
127.5	100	100	100	100	95	69	46	10	4	7	14	31	46	60	66	76	82	82
132.5	100	100	100	100	92	69	38	14	2	4	14	31	46	60	66	76	82	82
137.5	100	100	100	100	92	69	38	8	2	4	14	31	54	60	66	76	82	82
142.5	100	100	100	100	92	69	46	8	3	7	10	31	46	60	66	76	82	82
147.5	100	100	100	99	92	69	46	13	3	3	10	24	46	60	66	76	82	82
152.5	100	100	100	99	92	69	54	13	5	3	10	24	46	60	66	76	82	82
157.5	100	100	100	99	92	69	55	13	5	3	10	18	38	60	66	76	82	82
162.5	100	100	100	99	92	69	55	19	5	3	10	18	38	60	66	76	82	82
167.5	100	100	100	99	92	69	55	19	5	3	10	18	38	53	66	76	82	82
172.5	100	100	100	99	92	81	55	19	2	2	7	18	31	53	66	76	76	82
177.5	100	100	100	99	92	81	55	19	3	3	3	14	31	53	66	76	76	82

Figure 4f. January probability of contrail formation conditions at 150 mb, from 3WWM 105-9. The rectangle outlines the Persian Gulf region.

PROBABILITY OF CONTRAIL FORMATION (PERCENT)

MONTH JAN — PRESSURE LEVEL 100MB

LONGITUDE (EAST)	LATITUDE (TENTHS OF DEG. NORTH) 25	75	125	175	225	275	325	375	425	475	525	575	625	675	725	775	825	875
2.5	100	100	100	100	100	99	84	60	50	42	42	42	50	60	77	84	84	84
7.5	100	100	100	100	100	98	84	60	40	42	34	42	50	69	77	89	84	84
12.5	100	100	100	100	100	98	84	50	40	31	34	40	50	75	77	84	84	84
17.5	100	100	100	100	100	99	84	50	31	31	31	40	50	75	77	84	84	84
22.5	100	100	100	100	100	99	84	50	31	23	23	40	50	69	84	84	84	84
27.5	100	100	100	100	100	99	84	50	31	23	23	25	50	69	84	84	84	84
32.5	100	100	100	100	100	100	95	50	31	23	16	25	50	69	84	84	84	84
37.5	100	100	100	100	100	100	95	63	25	16	16	25	50	69	79	84	84	84
42.5	100	100	100	100	100	100	95	63	25	16	16	25	50	69	79	80	84	84
47.5	100	100	100	100	100	100	95	63	25	16	15	25	50	66	73	80	84	84
52.5	100	100	100	100	100	100	95	63	25	9	9	31	42	58	73	80	84	84
57.5	100	100	100	100	100	100	95	63	25	9	9	23	42	58	69	80	84	84
62.5	100	100	100	100	100	100	95	63	25	9	11	23	42	57	69	75	84	84
67.5	100	100	100	100	100	99	95	63	16	5	11	21	42	57	69	75	84	84
72.5	100	100	100	100	100	99	89	63	16	5	11	21	37	50	63	75	80	84
77.5	100	100	100	100	100	99	89	63	16	11	7	16	37	50	61	75	80	84
82.5	100	100	100	100	100	99	89	63	16	11	12	16	31	50	61	75	80	84
87.5	100	100	100	100	100	100	95	63	23	7	12	20	33	44	61	67	80	84
92.5	100	100	100	100	100	100	95	60	23	7	12	20	33	44	56	67	80	84
97.5	100	100	100	100	100	100	98	60	23	12	8	16	28	44	56	67	75	84
102.5	100	100	100	100	100	100	95	50	16	12	12	20	28	45	56	67	75	84
107.5	100	100	100	100	100	100	89	50	21	8	12	20	28	40	50	61	75	80
112.5	100	100	100	100	100	100	89	50	16	8	9	16	24	40	50	61	75	80
117.5	100	100	100	100	100	100	89	42	16	9	9	16	24	40	50	61	75	80
122.5	100	100	100	100	100	100	89	34	12	9	9	16	24	35	50	61	75	80
127.5	100	100	100	100	100	100	84	34	12	9	7	13	20	35	44	56	69	80
132.5	100	100	100	100	100	99	84	27	8	7	7	13	20	31	44	56	69	80
137.5	100	100	100	100	100	100	84	27	5	5	7	13	20	31	44	56	69	80
142.5	100	100	100	100	100	100	88	27	4	5	5	13	16	31	39	56	69	80
147.5	100	100	100	100	100	100	92	34	4	3	5	10	16	27	39	56	69	80
152.5	100	100	100	100	100	100	92	34	4	1	3	10	16	27	39	50	69	80
157.5	100	100	100	100	100	100	96	42	5	1	3	8	13	27	33	50	69	80
162.5	100	100	100	100	100	100	99	50	8	1	1	5	13	23	33	50	63	80
167.5	100	100	100	100	100	100	99	60	7	2	1	3	10	23	33	50	63	80
172.5	100	100	100	100	100	100	99	60	11	1	1	3	10	23	33	50	63	80
177.5	100	100	100	100	100	100	100	63	11	1	1	3	10	23	33	50	63	80

Figure 4g. January probability of contrail formation conditions at 100 mb, from 3WWM 105-9. The rectangle outlines the Persian Gulf region.

Height (ft MSL)	Percent Frequency of Occurrence	Height (ft MSL)	Percent Frequency of Occurrence
15,000	0.0	38,000	46.9
16,000	0.0	39,000	60.2
17,000	0.0	40,000	63.3
18,000	0.0	41,000	81.3
19,000	0.0	42,000	83.8
20,000	0.0	43,000	92.1
21,000	0.0	44,000	94.9
22,000	0.0	45,000	95.3
23,000	0.0	46,000	97.6
24,000	0.0	47,000	98.5
25,000	0.0	48,000	98.5
26,000	0.0	49,000	100.0
27,000	0.0	50,000	100.0
28,000	0.0	51,000	100.0
29,000	0.0	52,000	100.0
30,000	0.0	53,000	100.0
31,000	0.0	54,000	100.0
32,000	0.0	55,000	100.0
33,000	1.7	56,000	100.0
34,000	3.9	57,000	100.0
35,000	11.3	58,000	99.5
36,000	22.1	59,000	99.5
37,000	32.7	60,000	99.5

Figure 5. January POFs of conditions favorable for contrail formation, Riyadh, Saudi Arabia. (At 1,000-ft levels--extracted from DNCONTRL output.)

4.3.3 *Spatial and Seasonal Distribution.* Data for the 300-mb level from both studies was compared to see if spatial and seasonal distributions of favorable contrail formation conditions were similar. Since POFs of favorable contrail conditions in the USAFETAC study were computed at 500-foot intervals, the level closest to the 300-mb height had to be identified in order to compare USAFETAC results to those of 3WWM 105-9. AFCRC TR-59-270, *Atlas of 300-mb Wind Characteristics for the Northern Hemisphere*, was used to find the mean monthly height of the 300-mb level over the Persian Gulf. From the USAFETAC study, the POF at the 500-foot layer closest to the mean monthly height from the AFCRC atlas was chosen to compare probabilities of contrail formation at 300 mb.

Neither study showed any chance for contrail formation at the 300-mb level south of 22.5° N for any month of the year, but both studies showed that the POF of favorable contrail formation conditions at this level increase markedly northward.

USAFETAC POFs of favorable contrail formation conditions at Isparta, Turkey, and Mashhad, Iran, were compared to those at the closest gridpoint in 3WWM 105-9 study to see if seasonal variations were similar. The results of those comparisons are shown in Figures 6 and 7.

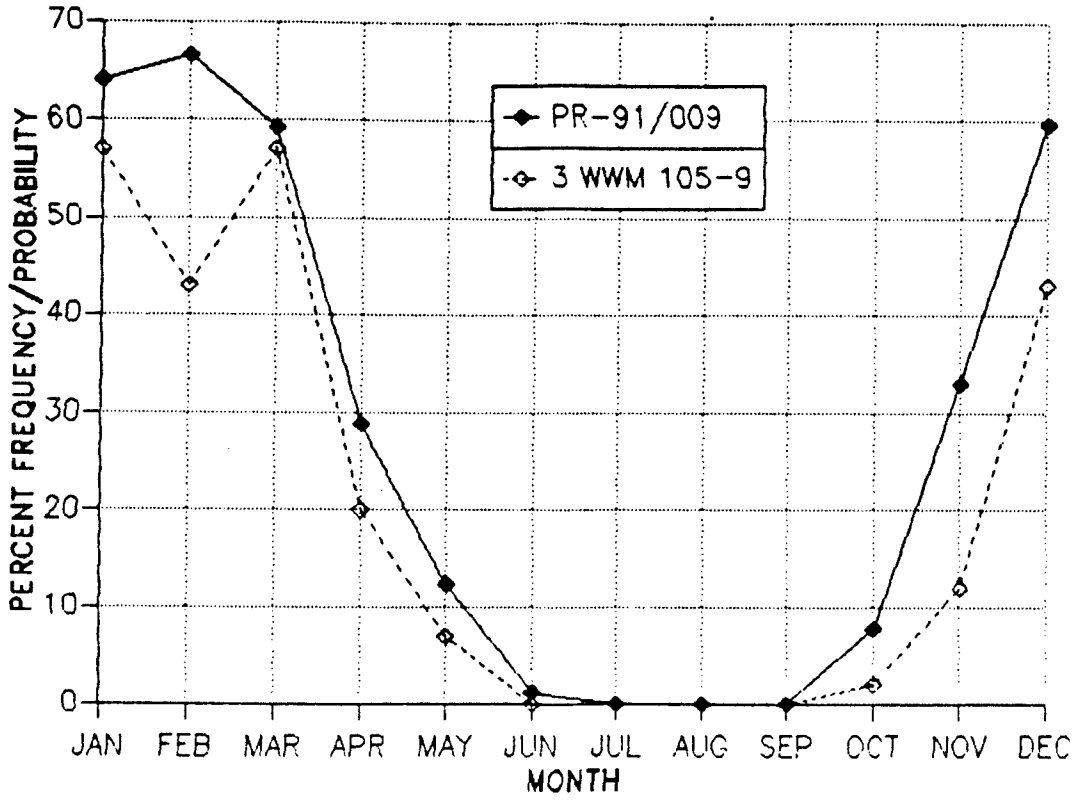

Figure 6. POF of favorable contrail conditions at 300 mb (USAFETAC) vs. probability of contrail conditions at 300 mb (from 3WWM 105-9) by month near Isparta, Turkey.

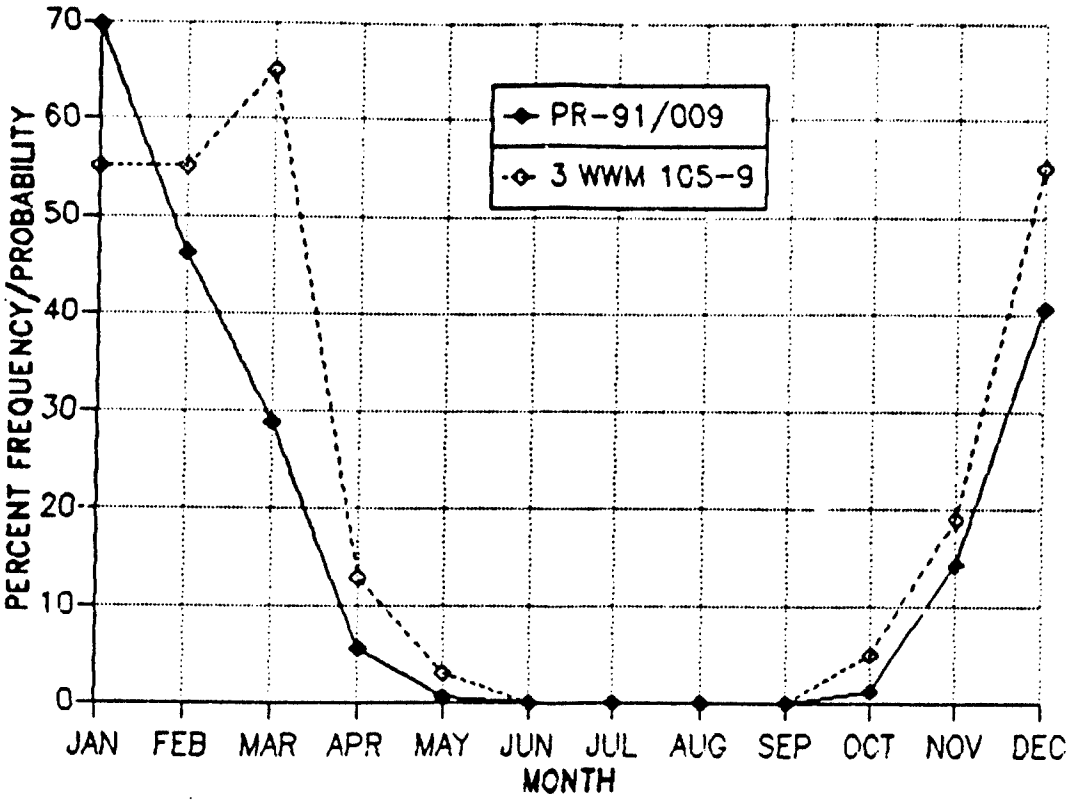

Figure 7. POF of favorable contrail conditions at 300 mb (USAFETAC) vs. probability of contrail conditions at 300 mb (from 3WWM 105-9) by month near Mashad, .

5. RESULTS OF THE USAFETAC STUDY.

Tables 1a through 19a give monthly POFs of favorable contrail conditions at 5,000-foot intervals. Tables 1b through 19b give monthly values of extreme minimum and maximum altitudes for contrail formation. Data is provided here for each of the 19 stations in the study. An asterisk (*) indicates "data not available."

TABLE 1a. Ankara, Turkey (171300)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0.7	0.2	0	0	0	0	0	0	0	0	0	0
25000	10.2	9.8	5.8	1.8	0	0	0	0	0	0	0.8	2.7
30000	79.6	78.7	67.7	42.6	8.8	1.1	0	0	0	8.3	31.8	59.8
35000	86.9	81.9	83.8	79.0	72.9	31.6	1.1	0.2	16.8	68.1	89.7	89.6
40000	65.9	55.7	55.7	57.8	60.5	38.1	2.8	2.3	42.2	83.8	86.7	78.3
45000	41.5	30.9	37.3	32.1	31.6	21.8	23.3	36.1	56.8	79.7	82.1	67.5
50000	29.9	23.5	32.1	23.1	18.0	25.2	59.8	72.7	63.8	75.2	72.2	58.0
55000	19.8	18.3	23.6	18.8	7.7	29.1	69.7	72.2	56.3	53.2	53.2	42.6
60000	8.3	8.7	12.1	6.3	3.3	17.8	51.0	45.3	24.3	18.5	23.6	25.0
65000	2.5	1.8	2.0	0.5	0	0.6	7.8	2.0	0.6	1.7	6.1	6.2
70000	0	0	0.5	0	0	0	0.7	0	0	0	0.3	0.6
75000	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1b. Ankara, Turkey (171300)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	17500	28000	44900	70000
FEB	19500	28100	44000	67000
MAR	21500	28900	45000	73000
APR	23000	30700	44100	67500
MAY	27500	33000	44000	64500
JUN	28500	38000	49000	68000
JUL	32500	46600	58100	73000
AUG	31500	45900	57500	67500
SEP	30500	40000	53900	66500
OCT	27000	34500	52400	67500
NOV	23500	31400	52800	90000
DEC	20500	29800	49800	70500

TABLE 2a. Izmir, Turkey (172200)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0.5	0	0	0	0	0	0	0	0	0
25000	7.0	6.7	6.8	0.6	0	0	0	0	0	0	0.3	2.2
30000	73.4	76.2	65.3	39.9	13.1	0	0	0	0	4.1	28.1	60.5
35000	88.5	82.7	80.6	81.0	82.9	38.5	1.7	0.6	22.9	72.0	92.9	90.0
40000	72.2	54.1	57.9	59.7	73.6	50.4	4.3	7.5	57.2	84.4	89.0	78.5
45000	60.0	40.4	41.9	41.7	65.7	37.6	50.1	68.2	75.9	82.1	88.7	74.4
50000	57.8	43.7	42.7	35.3	30.5	45.4	80.9	91.5	83.2	83.5	84.9	70.8
55000	48.0	37.8	37.9	26.2	23.9	52.3	87.8	89.5	76.9	64.3	67.6	63.8
60000	31.2	22.9	22.9	11.5	10.6	31.4	71.0	59.9	44.6	24.1	31.2	39.3
65000	12.7	9.6	5.5	2.6	1.8	2.4	9.0	3.7	3.4	2.7	7.3	10.8
70000	2.8	2.8	1.0	0	0.2	0	0	0.2	0	0	0.5	0.8
75000	0.3	1.3	0	0	0	0	0.2	0	0	0	0	0

TABLE 2b. Izmir, Turkey (172200)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	21000	28900	49300	77000
FEB	22000	28500	47000	84500
MAR	19000	29200	46900	82000
APR	24000	30800	46400	77500
MAY	26000	32400	47000	71000
JUN	30500	37900	52300	67000
JUL	32000	44800	58600	78500
AUG	33000	43800	57900	73500
SEP	31000	38800	55400	67500
OCT	56500	34100	53500	69500
NOV	22500	31300	51600	73000
DEC	23000	29700	52000	70500

TABLE 3a. Isparta, Turkey (172400)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	4.0	5.4	3.8	0.5	0	0	0	0	0	0	0.2	1.6
30000	64.1	66.6	59.2	28.8	9.6	0.3	0	0	0	3.3	25.4	50.3
35000	88.2	79.7	79.8	80.8	81.0	27.5	0.2	0.3	17.9	69.4	90.8	87.9
40000	70.5	56.5	55.3	62.1	71.8	42.7	2.6	4.2	49.4	83.3	87.6	77.5
45000	59.4	41.3	45.3	48.2	46.8	38.2	49.1	73.5	83.6	88.1	86.4	75.9
50000	54.9	42.0	47.7	40.2	32.9	54.0	90.7	97.4	93.1	89.7	85.3	75.0
55000	47.2	38.7	41.7	31.3	25.9	67.5	94.6	97.7	91.4	75.5	67.6	66.4
60000	26.2	25.3	28.0	16.2	11.7	48.0	83.0	83.2	68.4	40.5	39.6	40.9
65000	9.2	8.1	6.6	4.3	0.6	4.1	17.0	9.5	8.2	10.3	11.6	10.3
70000	2.5	1.3	1.1	0	0	0	0.2	0.5	0	1.1	2.9	0.9
75000	0.2	0	0.2	0	0	0	0	0	0	0	0	0

TABLE 3b. Isparta, Turkey (172400)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	21000	29600	51300	84500
FEB	21500	29400	49700	72500
MAR	20500	29600	49700	76500
APR	23500	31700	49500	69000
MAY	26500	33400	48900	68500
JUN	29000	40000	56100	68500
JUL	35000	45500	60600	71000
AUG	35000	44100	59800	72000
SEP	32000	39800	58600	69500
OCT	27500	34700	56500	90000
NOV	25000	31700	55300	73500
DEC	20500	30700	54700	72500

TABLE 4a. Diyarbakir, Turkey (172800)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	7.3	5.7	4.8	0.4	0	0	0	0	0	0.2	0.6	2.3
30000	64.3	58.2	54.8	19.5	6.4	0.2	0	0	0	2.0	21.5	51.0
35000	84.7	82.2	83.4	77.0	66.2	13.2	0	0	8.2	50.2	77.7	85.7
40000	73.9	65.9	56.9	69.5	64.3	21.5	1.4	2.4	27.1	73.4	82.4	75.6
45000	60.8	51.1	39.8	43.7	42.2	33.8	38.2	45.7	70.0	75.1	75.7	64.6
50000	55.0	47.2	40.2	38.0	38.6	54.1	76.7	81.5	81.1	73.9	72.5	58.4
55000	45.4	41.3	34.8	36.1	40.2	65.0	88.1	88.0	80.7	61.7	57.4	51.4
60000	28.6	29.9	19.9	19.1	31.5	61.3	77.9	81.5	71.0	42.0	40.4	31.0
65000	11.2	16.7	4.9	3.4	5.0	14.9	33.7	29.0	19.4	15.1	17.4	6.6
70000	3.8	3.3	0.9	0.5	0	0.4	0.4	1.7	0	0.4	3.9	2.2
75000	0.5	0	0	0	0	0	0	0.5	0.5	0	0.5	0

TABLE 4b. Diyarbakir, Turkey (172800)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	21000	29100	47600	76000
FEB	21500	29600	47200	74500
MAR	21500	29600	46300	73500
APR	24000	32300	47600	74000
MAY	27500	33700	49400	68500
JUN	29000	42600	57600	71500
JUL	36000	46200	59700	70500
AUG	36500	45600	59600	87500
SEP	32500	41800	57700	90000
OCT	25000	36300	53100	70500
NOV	23500	32400	51500	75000
DEC	22500	30300	59100	74500

TABLE 5a. Aleppo/Nairab, Syria (400070)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	[illegible]	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0.2	0.3	0	0	0	0	0	0	0	0	0
25000	1.8	1.5	1.7	0	0.1	0	0	0	0	0	0.2	0.2
30000	47.8	47.6	45.7	13.9	4.0	0	0	0	0	0.7	12.1	33.7
35000	84.9	78.5	80.5	79.9	68.6	5.9	0	0.2	1.9	53.7	83.6	83.1
40000	68.1	53.8	58.1	62.5	71.9	19.8	0	0.4	27.6	81.5	83.9	71.8
45000	53.0	44.3	39.7	46.1	46.8	46.6	59.0	80.6	94.3	91.4	82.1	66.4
50000	60.3	52.5	51.3	46.8	42.0	78.1	98.3	99.6	98.6	92.1	80.0	69.1
55000	58.1	52.8	48.5	44.8	40.9	85.3	99.1	99.8	98.3	79.9	67.2	63.5
60000	26.9	34.5	31.3	25.2	25.9	73.4	96.1	95.8	89.7	44.4	36.6	31.8
65000	9.7	9.0	7.1	6.0	1.3	11.1	36.4	17.3	16.3	8.7	6.2	6.0
70000	2.7	1.0	0.3	0	0.3	0.4	0.9	0.8	0	0.4	0	1.4
75000	0	0	0	0	0	0.4	0	0.9	0	0	0	0

TABLE 5b. Aleppo/Nairab, Syria (400070)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	23000	30800	50100	72500
FEB	19500	31100	49700	71000
MAR	17500	30700	49500	71000
APR	25500	32800	50200	68500
MAY	25000	34800	50600	73500
JUN	31500	43400	57400	84500
JUL	39500	45200	50800	70500
AUG	35000	44200	58800	81500
SEP	33500	41300	57900	69500
OCT	29500	36100	55400	70000
NOV	24500	33300	53000	69000
DEC	25000	32000	51300	73000

TABLE 6a. Damascus, Syria (400800)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0.2
30000	16.7	21.6	16.9	3.7	1.7	0	0	0	0	0.4	1.8	14.6
35000	72.4	63.0	65.6	69.2	49.1	2.1	0	0	1.7	32.8	60.5	70.3
40000	64.5	55.5	50.2	67.8	75.9	17.6	0.2	0.6	17.4	79.3	88.2	75.4
45000	63.1	58.3	51.0	52.7	61.3	71.1	74.1	87.0	93.0	99.8	90.5	76.0
50000	77.1	69.3	67.6	68.3	65.8	92.8	99.8	99.8	99.3	92.5	93.4	83.3
55000	82.0	77.3	72.0	68.8	67.7	97.4	100.0	100.0	99.6	88.8	88.8	79.2
60000	55.0	55.4	57.0	58.0	49.8	94.2	99.6	99.1	95.0	64.9	50.9	52.4
65000	17.9	23.0	14.7	17.1	5.0	26.2	53.6	31.2	12.0	8.4	12.5	10.9
70000	5.5	0.8	1.0	1.0	0	0	0.9	0	0	0.6	0.6	0
75000	1.3	0	0	0.5	0	0	1.0	0	0	0	0	0

TABLE 6b. Damascus, Syria (400800)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	22000	33800	53400	87500
FEB	24000	34000	52100	71000
MAR	22500	34000	52100	70500
APR	25500	34900	54000	77000
MAY	28500	36600	53600	68000
JUN	32500	43000	57200	69500
JUL	40000	44500	58900	82500
AUG	39000	43800	58500	68000
SEP	33500	41800	57700	67000
OCT	29500	37200	55300	70000
NOV	29500	35209	54600	70500
DEC	24500	34200	53400	68000

TABLE 7a. Bet Dagan, Israel (401790)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0.1	0.1	0	0	0	0	0	0	0.1	0	0	0
30000	15.5	15.2	11.8	0.8	0.4	0	0	0	0	0	1.6	9.2
35000	72.2	63.2	67.7	67.4	49.1	2.1	0	0	0.9	30.9	63.5	72.7
40000	72.0	58.8	60.3	75.1	81.7	17.5	0.1	0.3	24.9	82.8	89.8	83.8
45000	79.8	70.5	69.6	71.6	77.7	89.5	94.6	97.7	98.1	97.2	95.8	90.5
50000	90.1	86.8	86.9	84.6	86.2	96.7	98.9	98.8	98.9	97.8	97.7	96.2
55000	86.9	84.4	86.4	85.5	86.1	97.2	98.1	98.4	98.6	96.7	94.2	94.0
60000	63.1	63.0	66.7	69.3	70.7	93.5	97.9	98.0	97.7	80.9	71.2	73.5
65000	27.2	26.8	28.0	25.1	12.5	45.7	80.4	67.3	42.3	20.6	21.2	23.0
70000	6.4	9.9	7.3	5.0	2.1	13.2	18.9	18.3	16.8	5.7	4.8	6.3
75000	2.4	4.0	3.6	1.6	0	11.9	21.8	20.9	16.6	2.6	2.2	2.3

TABLE 7b. Bet Dagan, Israel (401790)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	24000	33900	60300	90000
FEB	25000	34500	60500	87500
MAR	25500	34800	60900	85000
APR	27500	35400	61000	86500
MAY	28000	36200	60400	83000
JUN	33000	42200	66000	90000
JUL	39500	43900	70000	90000
AUG	38500	43200	70100	90000
SEP	20500	41200	67600	90000
OCT	30500	37100	62400	89500
NOV	27000	35000	61600	90000
DEC	26000	34000	61500	83500

TABLE 8a. Tabuk, Saudi Arabia (403750)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	1.0	0.7	0.3	0.2	0	0	0	0	0	0	0	0
35000	35.3	29.9	32.5	28.9	12.6	0.4	0	0	0	5.7	17.9	31.4
40000	66.8	57.0	63.6	70.0	75.5	6.7	0.1	0.7	11.5	68.2	89.0	85.9
45000	90.0	85.7	89.8	78.6	89.8	94.4	92.0	95.8	98.1	97.4	97.3	93.1
50000	99.0	97.8	98.7	97.1	97.9	99.7	100.0	99.9	99.9	99.4	99.9	98.7
55000	99.8	98.4	99.8	99.5	98.7	99.7	100.0	99.8	99.7	99.7	99.2	99.4
60000	95.0	94.5	95.7	97.3	97.2	99.5	100.0	99.8	99.8	98.4	96.7	95.9
65000	47.0	57.8	57.7	61.3	40.8	67.9	85.7	72.6	41.8	39.9	44.5	51.5
70000	7.3	4.3	4.0	0	0.2	1.5	0.7	0.7	0.2	0.8	2.7	4.1
75000	1.9	0.6	0.5	0	0	0.4	0	0.2	0.4	0.2	0.4	0.6

TABLE 8b. Tabuk, Saudi Arabia (403750)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	29000	37500	63100	79500
FEB	28000	38600	63000	90000
MAR	29000	38100	63000	80500
APR	30000	38100	63300	70500
MAY	31500	38400	62200	73000
JUN	35000	42500	63700	80500
JUL	40000	43600	64500	71000
AUG	39500	43200	64100	77000
SEP	36500	41700	63200	78000
OCT	31000	38900	62700	76000
NOV	31000	37500	62400	78500
DEC	28000	36900	62900	84500

TABLE 9a. Medinah, Saudi Arabia (404300)–POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	0	0	0.3	0	0.3	0	0	0	0	0	0.2	0.2
35000	5.1	2.5	10.4	3.2	1.8	0	0	0	0	0.2	1.6	5.6
40000	54.9	59.8	51.3	52.5	52.8	3.3	0.3	0.3	7.7	48.2	77.4	86.7
45000	95.8	96.1	95.4	90.4	95.9	99.1	98.2	98.5	100.0	99.1	97.8	98.3
50000	99.4	100.0	99.3	99.1	100.0	100.0	99.7	99.7	100.0	99.8	99.5	99.7
55000	99.3	100.0	100.0	98.8	100.0	100.0	99.7	99.7	100.0	100.0	98.7	100.0
60000	99.3	99.6	99.6	99.1	99.0	99.7	100.0	100.0	100.0	99.5	98.6	98.3
65000	80.0	81.2	89.8	84.7	76.1	87.5	86.1	80.6	62.1	64.4	66.1	77.6
70000	11.3	6.7	9.1	2.2	0.8	1.8	0.8	0.7	0.3	0.3	3.8	7.0
75000	2.6	0	1.0	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3

TABLE 9b. Medinah, Saudi Arabia (404300)–Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	32500	39100	64900	88000
FEB	30500	39800	64500	73500
MAR	30000	39700	65300	75500
APR	33500	39600	65200	77500
MAY	29500	39800	64100	77500
JUN	35500	42200	65100	77000
JUL	35500	42900	65000	77500
AUG	39500	42800	64600	77500
SEP	37500	41500	64000	84500
OCT	34500	40100	63600	76500
NOV	30000	38800	63300	77000
DEC	27500	38000	64500	86000

TABLE 10a. Riyadh, Saudi Arabia (404370)--POF of contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	0	0	0	0	0	0	0	0	0	0	0	0
35000	11.3	7.9	20.1	7.1	0.4	0	0	0	0	0	2.8	10.9
40000	66.7	54.5	63.8	58.8	53.0	0.4	0	0	4.0	37.2	78.3	87.6
45000	95.3	94.7	97.7	89.3	97.6	99.2	98.5	100.0	99.6	99.0	98.5	98.6
50000	100.0	100.0	99.5	100.0	99.2	100.0	99.6	100.0	100.0	100.0	99.2	99.2
55000	100.0	100.0	100.0	99.6	99.6	100.0	99.6	100.0	100.0	100.0	99.6	99.2
60000	99.5	100.0	100.0	99.6	99.2	100.0	99.6	100.0	100.0	100.0	99.6	99.1
65000	88.3	89.4	90.3	95.0	85.1	97.0	94.4	93.2	81.2	82.5	83.9	79.5
70000	13.2	12.4	13.9	5.6	0	0.4	0	0	0	0.8	4.5	8.7
75000	2.0	0	0	0	0	0	0	0	0	0	0	0

TABLE 10b. Riyadh, Saudi Arabia (404370)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	33000	38300	63500	77000
FEB	32000	39300	65000	73000
MAR	33000	38400	63500	72500
APR	34000	39300	65100	71000
MAY	31500	40200	65100	78000
JUN	39500	42700	65900	70500
JUL	41000	43100	65600	69000
AUG	40500	42800	65500	69000
SEP	38500	41800	64400	69500
OCT	35500	40200	64500	71000
NOV	34500	38500	63400	72500
DEC	32500	37800	62200	73500

TABLE 11a. Dhahran, Saudi Arabia (404160)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	0.3	0	0	0.3	0	0	0	0	0	0	0	0
35000	22.6	18.8	22.7	10.1	2.1	0	0	0	0	0.7	3.6	16.8
40000	61.7	57.5	57.7	64.3	48.4	1.8	0.1	0	1.3	46.5	79.4	85.7
45000	92.4	93.3	95.0	88.4	96.9	96.9	89.8	94.1	98.4	99.4	96.4	98.0
50000	99.7	99.2	99.7	99.4	99.5	99.8	99.8	99.9	100.0	100.0	99.7	99.7
55000	99.8	99.2	99.8	99.8	99.8	99.8	99.8	100.0	100.0	100.0	99.7	99.7
60000	98.5	99.1	99.0	99.8	99.6	99.6	100.0	99.7	99.8	100.0	99.8	99.3
65000	65.4	72.8	82.1	89.9	78.7	89.6	94.9	85.0	70.7	63.0	68.4	64.5
70000	6.7	3.4	9.2	2.5	0.4	2.1	0.4	0.6	1.4	0.7	3.1	5.9
75000	0	0	0.3	0	0.2	0.2	0	0.4	0	0.2	0	0

TABLE 11b. Dhahran, Saudi Arabia (404160)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	29500	38500	63000	74500
FEB	31000	38900	62900	73000
MAR	31500	38500	63200	84000
APR	29500	38900	63900	73000
MAY	32500	40000	63500	77000
JUN	37500	43000	64300	81000
JUL	39500	43800	64200	72500
AUG	40500	43600	64000	78500
SEP	37500	42300	63600	74000
OCT	34000	40300	63200	75500
NOV	33000	38600	63100	71500
DEC	30500	37600	62700	72500

TABLE 12a. Kuwait IAP, Kuwait (405820)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0.2	0	0	0	0	0	0	0	0
25000	0	0	0	1.2	0	0	0	0	0	0	0	0
30000	1.3	1.7	0.5	0.2	0	0	0	0	0	0	0.3	0.9
35000	43.4	42.4	41.8	32.0	6.8	0.2	0	0	0	7.4	22.0	43.1
40000	70.3	60.3	62.4	72.1	60.9	4.0	0	0.2	5.9	59.6	88.2	86.2
45000	85.0	88.4	86.1	82.2	92.3	87.9	79.7	88.2	96.0	98.8	97.1	93.5
50000	98.5	97.6	97.8	97.4	99.5	99.5	100.0	100.0	100.0	100.0	99.8	98.9
55000	99.0	98.8	98.5	99.7	99.5	99.6	100.0	100.0	100.0	98.8	99.6	99.4
60000	90.4	92.7	93.9	98.5	98.4	99.6	100.0	100.0	100.0	98.8	96.9	94.8
65000	53.8	59.9	56.6	79.5	69.7	89.0	94.2	90.7	66.0	54.9	51.7	51.0
70000	10.0	3.8	7.4	2.8	0.8	1.4	1.5	0.5	0.5	0.2	3.3	6.2
75000	1.6	0	0.3	0	0	0.7	0	0	0.2	0	0	0

TABLE 12b. Kuwait IAP, Kuwait (405820)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	29000	36900	57400	76500
FEB	26000	37000	58800	74500
MAR	29000	37600	60000	77000
APR	17500	37700	61100	71000
MAY	32000	39500	61300	90000
JUN	33500	43300	63300	85000
JUL	41000	44500	63700	72000
AUG	40000	44000	63200	89000
SEP	37500	42400	62600	87500
OCT	32500	39300	61100	72500
NOV	27000	37300	60900	73000
DEC	28500	36200	60900	72500

TABLE 13a. Baghdad, Iraq (406500)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	1.1	0	0	0	0	0	0	0	0	0	0	0
30000	28.3	24.1	15.5	2.8	0	0	0	0	0	0.3	2.5	12.7
35000	78.1	68.6	70.0	69.3	35.0	1.8	0	0	0.6	31.3	64.4	81.0
40000	71.7	55.3	61.0	79.1	75.8	11.3	0.5	0.3	18.4	83.1	87.6	82.7
45000	70.6	73.7	65.8	68.8	74.5	83.3	75.8	88.0	94.3	98.0	90.0	87.5
50000	79.9	80.6	79.7	81.2	89.0	98.9	99.7	99.7	99.7	99.7	94.7	92.0
55000	64.5	77.2	78.1	89.1	87.6	99.3	99.7	100.0	99.5	99.2	92.3	85.4
60000	31.5	56.5	58.0	76.3	81.8	98.3	99.1	99.5	98.2	82.5	68.2	62.3
65000	7.5	24.1	16.8	25.9	23.0	58.1	83.4	67.4	39.1	15.9	15.7	15.4
70000	1.0	8.2	0	0	0.7	3.3	3.7	0.7	1.6	0	1.4	2.6
75000	0	0	0	0	0	0.7	0	0	0	0	0	1.0

TABLE 13b. Baghdad, Iraq (406500)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	22500	32600	52600	70000
FEB	22500	33400	53800	73000
MAR	26000	34400	52900	69500
APR	27500	35200	55800	86000
MAY	31000	37600	56900	73000
JUN	34000	43300	60600	86500
JUL	39000	44900	60900	74000
AUG	40000	44100	59700	70000
SEP	34000	42900	58600	71500
OCT	29000	37600	56100	68500
NOV	27500	35400	55200	70500
DEC	27000	33900	54900	76000

TABLE 14a. Mashhad, Iran (407450)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	2.5	2.6	1.4	0	0	0	0	0	0	0	0	0
30000	69.7	46.1	28.8	2.1	0	0	0	0	0	0	2.0	0
35000	88.3	83.2	72.1	79.5	26.4	0.9	0	0	1.2	47.2	80.9	85.3
40000	72.6	70.0	64.3	75.2	46.7	5.9	0.9	0.9	4.9	71.9	94.9	74.1
45000	47.7	43.1	47.2	65.2	41.2	53.1	49.5	76.6	84.2	90.9	92.4	77.5
50000	58.7	57.4	53.8	70.2	78.7	96.3	97.6	98.7	94.7	89.1	90.7	78.3
55000	90.0	100.0	50.0	50.0	66.7	100.0	97.3	98.1	96.2	75.0	100.0	50.0
60000	50.0	100.0	40.0	66.7	100.0	100.0	100.0	100.0	81.8	62.5	25.0	*
65000	0	0	0	25.0	*	80.0	50.0	33.3	12.5	33.3	0	*
70000	*	*	*	*	*	0	0	0	0	0	0	*
75000	*	*	*	*	*	0	0	0	0	0	0	*

TABLE 14b. Mashhad, Iran (407450)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	24000	29800	45600	64500
FEB	22500	30400	43500	62500
MAR	24500	32900	45900	64500
APR	30000	38200	47800	65000
MAY	30500	38200	49900	61000
JUN	34500	44200	54600	69500
JUL	38500	45400	54600	67000
AUG	39000	44300	54500	68500
SEP	34500	43500	53900	65000
OCT	31000	37200	50000	67000
NOV	23500	33200	48800	60000
DEC	25500	31600	45600	58500

TABLE 15a. Tehran, Iran (407540)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0.5	0	0	0	0	0	0	0	0	0	0	0
25000	2.0	1.6	0.3	0	0	0	0	0	0	0	0	0.6
30000	56.2	39.2	21.0	4.3	0.4	0	0	0	0	0	4.0	27.6
35000	81.9	77.1	75.7	78.9	28.7	0.7	0	0	0.9	39.0	70.0	87.5
40000	69.3	63.1	64.8	76.8	54.8	4.6	0.5	0	16.3	83.2	81.3	81.3
45000	62.5	55.1	59.0	61.0	57.1	64.4	55.1	68.2	93.9	95.5	87.7	84.0
50000	59.8	62.1	62.9	71.7	77.8	98.3	99.3	99.4	100.0	98.0	90.5	85.7
55000	48.0	63.2	66.7	71.4	82.4	98.1	100.0	99.3	100.0	92.9	57.1	80.0
60000	25.0	43.8	52.9	46.2	66.7	97.2	100.0	100.0	100.0	90.0	85.7	100.0
65000	11.1	37.5	0	20.0	12.5	56.3	81.3	59.1	33.3	0	0	*
70000	0	25.0	0	0	0	9.1	0	0	0	0	0	*
75000	0	25.0	0	0	0	12.5	0	0	0	0	0	*

TABLE 15b. Tehran, Iran (407540)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	19000	29900	44000	65500
FEB	23000	30800	45100	76000
MAR	22500	32500	46400	63000
APR	28000	33900	48000	65000
MAY	30000	38000	49800	65500
JUN	33000	44100	54000	81500
JUL	40000	45200	54200	68500
AUG	40500	44800	55200	69000
SEP	35000	42200	53600	67500
OCT	31500	36600	48700	64000
NOV	28000	34400	46800	63500
DEC	24500	31900	44900	60500

TABLE 16a. Kerman, Iran (408410)--POF contrail formation conditions at 5,000-ft intervals, by month

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	5.0	6.9	1.5	0	0	0	0	0	0	0	0	0
35000	48.7	48.6	43.0	31.4	1.5	0	0	0	0	1.0	0.9	1.7
40000	66.7	64.3	71.5	70.1	35.6	0	1.8	0	5.0	7.2	23.9	50.9
45000	85.3	83.8	89.2	81.6	89.5	69.4	56.9	73.6	95.0	97.8	88.9	92.5
50000	93.7	95.3	98.3	96.2	98.2	97.1	100.0	100.0	100.0	97.5	95.6	92.4
55000	91.3	97.4	98.7	96.6	100.0	96.6	100.0	100.0	100.0	89.7	93.8	97.8
60000	90.9	94.6	95.0	96.0	96.3	97.7	95.8	100.0	100.0	85.7	93.3	100.0
65000	25.0	48.3	50.0	79.2	75.0	86.0	95.0	95.7	76.5	57.1	46.7	53.8
70000	8.3	21.1	10.0	11.1	0	17.8	18.3	0	0	20.0	18.2	0
75000	0	5.9	0	0	0	3.1	0	0	0	0	0	0

TABLE 16b. Kerman, Iran (408410)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	25500	36700	53000	71500
FEB	27500	35900	54900	77000
MAR	28500	37000	53400	70000
APR	31000	37500	55000	72000
MAY	33500	41200	55500	68500
JUN	41000	44700	59400	77500
JUL	38500	45100	57300	70500
AUG	41000	44500	57000	68500
SEP	39000	43100	55300	68000
OCT	28500	38700	53500	70000
NOV	30000	38300	53600	73500
DEC	29500	35800	53000	68500

TABLE 17a. Khamis Mushait, Saudi Arabia (411140)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	0	0	0	0	0	0	0	0	0	0	0	0
35000	0.2	0	0	0	0.2	0	0	0.1	0	0.1	.1	0
40000	52.5	49.7	40.1	32.2	26.8	2.8	1.5	2.8	11.5	31.8	59.6	72.6
45000	98.9	98.3	98.6	97.7	97.9	99.4	98.2	97.6	98.9	99.3	99.4	99.1
50000	99.8	100.0	100.0	99.8	99.2	99.8	99.8	99.2	100.0	99.9	100.0	100.0
55000	99.8	99.7	100.0	100.0	99.6	99.6	100.0	99.1	100.0	99.8	99.8	100.0
60000	100.0	100.0	100.0	100.0	99.0	99.6	99.6	99.1	100.0	99.8	99.6	100.0
65000	97.5	98.2	97.0	98.2	92.3	87.9	80.3	76.9	76.3	87.1	92.3	97.5
70000	10.7	15.0	15.6	6.0	1.3	2.2	2.0	1.5	2.7	1.0	3.8	9.0
75000	0.9	0.7	0	0.8	0.3	0.7	0	0.2	0.4	0	0.4	0.5

TABLE 17b. Khamis Mushait, Saudi Arabia (411140)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	33500	40200	63800	76000
FEB	35500	40700	63400	76500
MAR	35000	40600	64400	73500
APR	36000	40900	64100	79000
MAY	30500	41200	63000	79000
JUN	36500	42100	63800	87500
JUL	38000	42300	63500	73500
AUG	34000	42100	63700	85000
SEP	36500	41500	63500	85500
OCT	32000	40600	64100	76500
NOV	34000	40100	63700	76500
DEC	36500	39700	64000	90000

TABLE 18a. Seeb, Oman (412560)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	0	0	0	0	0	0	0	0	0	0	0	0
35000	10.2	4.7	6.9	0.4	0	0	0	0.3	0	0	1.2	4.6
40000	53.4	30.3	53.4	40.4	29.8	0	0	0.3	0.4	10.6	60.7	83.7
45000	97.0	98.1	97.4	95.5	98.8	98.6	99.2	99.3	100.0	99.6	99.1	100.0
50000	100.0	100.0	100.0	100.0	99.6	99.6	100.0	99.7	100.0	100.0	100.0	100.0
55000	99.5	99.5	100.0	100.0	100.0	100.0	100.0	99.6	100.0	100.0	100.0	100.0
60000	99.5	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
65000	89.0	93.9	93.9	98.0	91.9	95.5	94.3	92.0	74.5	78.9	85.3	81.4
70000	6.1	95.0	9.7	1.5	0.5	0.4	0.5	0	0	0	1.4	1.3
75000	0	0.5	0	0	0.5	0.4	0	0	0	0	0	0

TABLE 18b. Seeb, Oman (412560)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	33500	40300	64000	72000
FEB	35000	40400	64900	84500
MAR	32000	40400	63500	70000
APR	37000	40500	65200	70500
MAY	37000	41700	64400	70000
JUN	38500	42400	64100	70500
JUL	37500	42500	63500	69000
AUG	40000	42500	63700	69000
SEP	39000	42200	63500	75500
OCT	37500	40900	63600	74000
NOV	35500	40100	63900	72500
DEC	35000	40200	64600	74500

TABLE 19a. Salalah, Oman (413160)--POF contrail formation conditions at 5,000-ft intervals, by month.

Altitude (ft MSL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10000	0	0	0	0	0	0	0	0	0	0	0	0
15000	0	0	0	0	0	0	0	0	0	0	0	0
20000	0	0	0	0	0	0	0	0	0	0	0	0
25000	0	0	0	0	0	0	0	0	0	0	0	0
30000	0	0	0	0	0	0	0	0	0	0	0	0
35000	0.7	0.8	1.2	0	0	0	0	0	0	0	0	0.6
40000	69.6	74.4	58.5	60.6	19.5	1.2	3.8	0.6	18.1	59.7	74.5	84.7
45000	100.0	100.0	100.0	99.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
50000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
55000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
60000	99.1	100.0	100.0	100.0	100.0	99.3	100.0	100.0	100.0	99.3	100.0	100.0
65000	95.4	95.2	99.2	92.7	85.8	82.9	63.8	60.3	68.6	88.0	90.0	95.3
70000	2.2	9.4	5.0	1.1	1.0	1.6	0	0	1.6	0.7	3.6	3.8
75000	0	1.3	0	0	0	0	0	0	0.8	0	0	0

TABLE 19b. Salalah, Oman (413160)--Mean and extreme altitudes for contrail formation by month.

MONTH	EXTREME MINIMUM	MEAN MINIMUM	MEAN MAXIMUM	EXTREME MAXIMUM
JAN	31500	39200	66000	72000
FEB	33500	40500	66500	77000
MAR	33000	39100	66400	71500
APR	35000	40600	65700	70500
MAY	37000	41000	64900	90000
JUN	41000	43400	65200	86500
JUL	41000	43200	65500	70500
AUG	32000	43200	64700	69000
SEP	39500	42000	64700	69000
OCT	37000	41300	64500	69000
NOV	34500	39400	65200	72000
DEC	33000	38300	64800	72000

6. SUMMARY AND CONCLUSIONS.

USAFETAC/DNO developed the DNCONTRL program to determine climatological mean and extreme maximum and minimum altitudes at which contrails are likely to form over a given upper-air station. The program also determines percent occurrence frequency (POF) of conditions favorable for contrail formation at each 500-foot level in the atmosphere, from 10,000 feet to the top of the sounding or to 100,000 feet, whichever is lower.

DNCONTRL was applied to 19 upper-air stations in the area of the Persian Gulf specified for this study. The study area was within a box delineated by lines from 10° to 40° N, and from 30° to 60° E.

DNCONTRL satsifactorily determines the presence of conditions favorable for contrail formation by calculating a critical temperature at 500-foot intervals in the vertical. If the ambient temperature at a level is less than or equal to the critical temperature, meteorological conditions are conducive for contrail formation. Monthly values of mean and extreme minimum and maximum altitudes for contrail formation over each station were determined. A POF of favorable contrail formation conditions throughout the atmosphere was also calculated for each of the 19 stations, for each month of the year.

The results of this study were consistent with those from a similar study of the entire northern hemisphere developed by 3WW.

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ABBREVIATIONS, ACRONYMS, and SYMBOLS

AFCRC	Air Force Cambridge Research Center (now Phillips Laboratory, Geophysics Directorate)
AFGWC	Air Force Global Weather Central
DNCONTRL	Software written by USAFETAC/DNO to find mean and extreme maximum and minimum altitudes of contrail formation
DNO	Operations Applications Development Section, USAFETAC
EBCDIC	Extended Binary Coded Decimal Interchange Code. A binary code for representing data, used by IBM computers.
ECA	Systems Support Section, USAFETAC
ECAUARDR	Upper-Air Reader program. Written by USAFETAC/ECA, reads upper-air data from tape and creates a file on disk.
EXTRCDTG	Program written by USAFETAC/ECA to convert a flat file to a SAS permanent dataset.
IR	Iran
IQ	Iraq
IS	Israel
JCL	Job Control Language. Instructions to the operating system governing execution of a computer program and describing its input and output.
KW	Kuwait
mb	Millibars
MEANS	Software routine within the SAS language that computes various statistics.
MO	Month
MSL	Mean sea level. Used as a qualifier in measurements of altitude, to distinguish from "above ground level" (AGL).
OM	Oman
p	Atmospheric pressure
PDS	Permanent Dataset. Structure of data compatible with the SAS language.
POF	Percent occurrence frequency
POR	Period of record. Chronological content of a collection of data.
RH	Relative humidity
SAS	Statistical Analysis System. Fourth-generation computer language used at USAFETAC
SD	Saudi Arabia
SY	Syria
TABULATE	Software routine within the SAS language that computes and displays various statistics.
T_c	Critical temperature
3WW	Third Weather Wing
TROPFCST	Computer program for forecasting contrails, used at AFGWC.
TU	Turkey
USAFETAC	United States Air Force Environmental Technical Applications Center.

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